

## *Chapter 4*

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# ***Positional and Restraint Asphyxia***

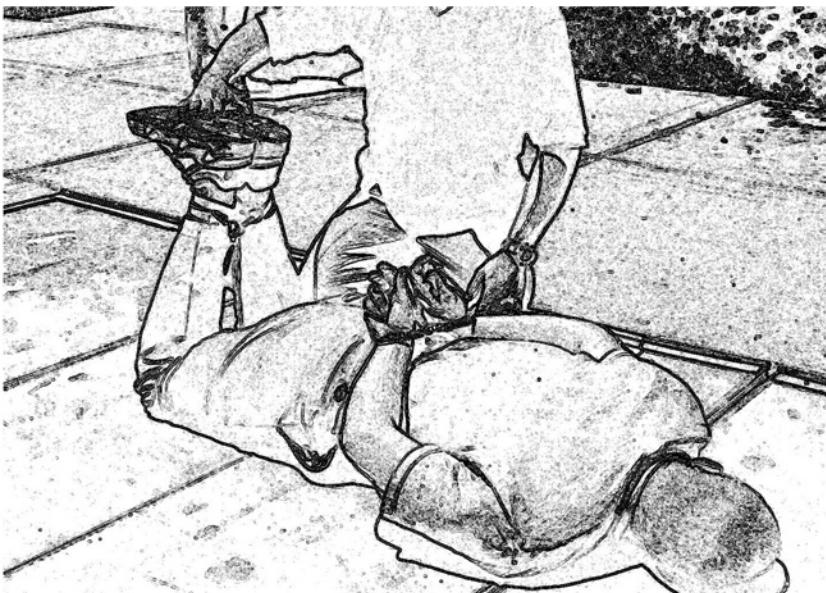
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### *INTRODUCTION*

The use of physical restraint to control violent, uncooperative, or combative individuals is to be expected in the law enforcement setting. Furthermore, the more violent, combative, or uncooperative an individual, the greater and greater degrees of force required to restrain such persons. When an individual dies under such circumstances, it becomes a legitimate question whether the restraint process or specific method itself had any causal relationship with the death or whether the death was predicated more upon the circumstances that led to restraint in the first place. Clearly, certain methods of restraint have been reported to be potentially harmful to individuals and as a result, certain “choke hold” maneuvers are no longer used by most police or law enforcement agencies because of the risk they apparently represent (1,2).

Similarly the “hoggie,” “hobble,” or maximal restraint position has also come under scrutiny as a possible factor in the deaths of individuals being brought into custody (3). In these positions, individuals are bound in the prone position with their arms handcuffed behind their backs and their knees flexed with their ankles bound together and then secured (with varying degrees of freedom) to the handcuffs (see Figs. 1 and 2). The literature includes multiple reports of deaths of individuals placed into these (or similar) positions, and the conclusion of some authors has been that the deaths were directly attributable to the restraint positioning (4–6). The rationale for this conclusion was that the position impaired the ability of the individual to breathe and ventilate to such a degree that hypoxemia (low oxygen levels in the blood) secondary to

From: *Forensic Science and Medicine: Sudden Deaths in Custody*  
Edited by: D. L. Ross and T. C. Chan © Humana Press Inc., Totowa, NJ



**Fig. 1.** Hobble prone restraint position. The position is similar to the hogtie position, but there is greater distance between the wrist and ankles when secured together allowing less flexion of the knees.

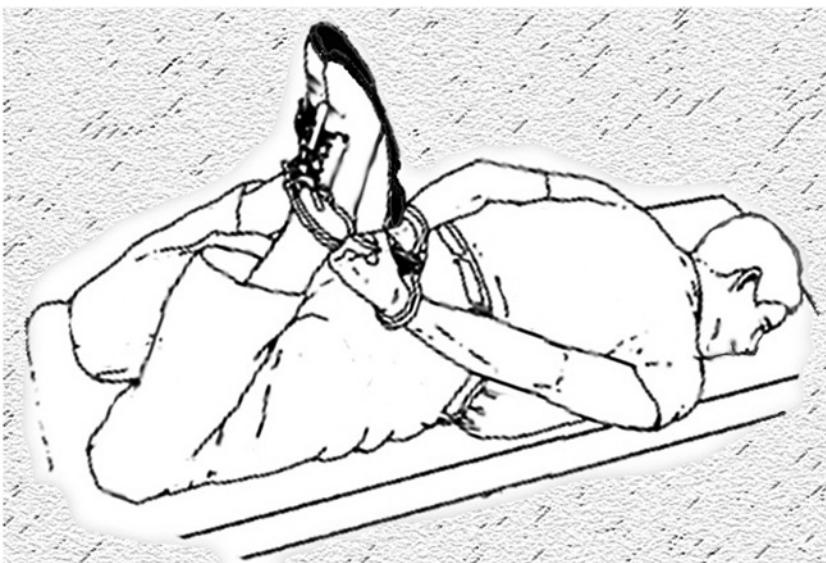
hypoventilatory failure occurred, and that the degree and duration of the hypoxemia was sufficient to cause death. With the understanding that this argument is predicated on certain pathophysiological processes taking place, it is worthwhile to review, albeit briefly, the normal physiology of the most important aspects of respiration.

#### *GAS EXCHANGE AND VENTILATION*

Ultimately, the process of asphyxiation is the death of the individual and the associated failure of critical organ systems owing to lack of oxygen delivery. The delivery of appropriate amounts of oxygen to the tissues of the body is dependent on a variety of factors. For the purposes of this chapter, the most important factor is that oxygen actually gets into the blood (oxygen transport from the blood to tissues is assumed). Oxygenation of the blood is in turn dependent on two major processes. First and foremost is ventilation. Adequate amounts of gas must be delivered to the lung tissue or alveoli in order for proper oxygenation of the blood to occur (movement of gas also requires that the airway is patent). Assuming adequate ventilation takes place, then appropriate gas

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**Fig. 2.** Hogtie prone restraint position. The individual is bound in the prone position with arms handcuffed behind the back and knees flexed with ankles bound together and secured to the handcuffs.

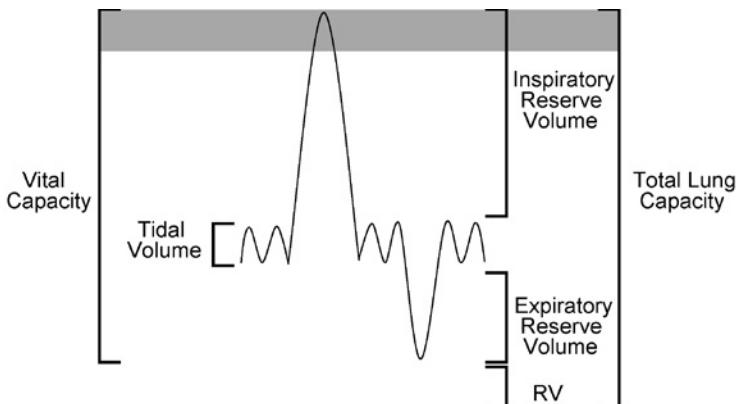
exchange must also occur in order to assure oxygen delivery to the blood and subsequently to the tissues.

Ventilatory parameters can generally be measured by standard pulmonary function testing with spirometric functions being the most useful parameters to examine when looking at measures of gas movement. Measurement of gas exchange can be more difficult, however, the alveolar-arterial oxygen ( $[A-a]O_2$ ) gradient is probably the most useful screening parameter to quantitate gas exchange. This number is calculated from the following equation:

$$(A-a)O_2 \text{ gradient} = (FIO_2 \times P_B - PaCO_2/RQ) - PaO_2$$

where  $FIO_2$  is the fraction of inspired oxygen tension,  $P_B$  is the barometric pressure,  $PaCO_2$  is the partial pressure of carbon dioxide in the arterial blood, RQ is the respiratory quotient (respiratory exchange ratio) and  $PaO_2$  is the partial pressure of oxygen in the arterial blood. A normal  $(A-a)O_2$  gradient is less than 10–15 mmHg (7).

A normal-sized individual in a resting state has a tidal volume of approximately 500 cc per breath. With a normal ventilatory rate of 12–16 at rest. This represents a baseline minute ventilation of approximately 6–8 L per minute. Vital capacity is defined as the amount of air an individual can take into his or



**Fig. 3.** Graph of lung volumes. Tidal volume is the volume of air in a normal breath in an adult (approximately 500 cc). Inspiratory reserve volume is the volume of air associated with maximal inspiration (excluding tidal volume). Expiratory reserve volume is the volume of air associated with maximal expiration (excluding tidal volume). The residual volume (RV) is the remaining air in the lungs after maximal expiration. Vital capacity is defined as the amount of air an individual can take into his or her lungs after a maximal inspiration (tidal volume plus inspiratory and expiratory reserve volumes). The 13% decrease in forced vital capacity with the hogtie restraint position is shown by the shaded region. The graph demonstrates the tremendous pulmonary reserve that minimize the impact of any respiratory decrement seen with the restraint position.

her lungs after a maximal inhalation. Figure 3 demonstrates various measures of lung volume. Forced expiratory volume in 1 second ( $FEV_1$ ) is defined as the volume of air one can blow out in 1 second after a maximal inhalation and the forced vital capacity (FVC) is the volume of air one can blow out after a maximal inhalation. Finally, the  $FEV_1$ :FVC ratio is a parameter often examined as part of routine pulmonary function testing and in normals it is about 83% (7). Pulmonary function testing also reveals that a person instructed to breathe as rapidly and deeply as possible for a period of about 30 seconds achieves a maximum voluntary ventilation (MVV) of about 160–180 L per minute.

A normal person has tremendous reserves in his or her ability to ventilate. At maximal workloads ( $\dot{V}O_{2\text{max}}$ ), most individuals do not approach a level of ventilation that exceeds 70% of their MVV. Indeed, once an individual passes the age of 30 years, this percentage drops off even further because maximal oxygen consumption is dictated by cardiac output rather than ventilation (8). Thus, it should be obvious that in order for a person to asphyxiate (from any cause) a dramatic reduction in the ability to ventilate must occur.

## HISTORY

Although a number of deaths have certainly occurred in individuals who have been placed in restraint positions, the actual physiological role of the restraint position in these deaths is unclear. There is no question that the entity of positional asphyxia exists. The term was apparently first used by Bell in a study (9) describing the deaths of 30 individuals in Broward County, Florida. No other significant risk factors for death were noted in this original description of positional asphyxia. The unifying feature of the vast majority of these deaths was that the individuals were discovered in positions that resulted in upper airway obstruction. These situations included hyperflexion of the head and neck or lying face down on a suffocating object. Alcohol intoxication (or other depressant drugs) was a major risk factor in these cases as well, and explained why these victims did not move from the position that caused the upper airway obstruction. In four cases, the torso was found to be hyperflexed accounting for a mechanical inability to breathe.

Another form of asphyxia has been termed *mechanical asphyxiation*. This has been associated with the use of a vest, jacket, or even posey restraints, and primarily has been described in the geriatric nursing home population. In this situation, asphyxiation occurs when these restraints accidentally wrap around the necks of the individuals and the result is simple strangulation (10–13). In other cases, individuals became suspended from either a bed or a chair by their restraints with resulting chest constriction to the point of mechanical ventilatory impairment and death (14,15). Thus, in its original form, the term *positional asphyxiation* described, in the vast majority of cases, either upper airway obstruction secondary to the position of the individual or simple strangulation owing to the position.

## CASE REPORTS

A number of case reports document the deaths of individuals who are restrained by law enforcement. However, these reports can only infer the role of the restraint in these deaths. Examining these reports reveals a pattern of deaths that is, without question, repetitive. In 1985, Wetli and Fishbain reported seven cases of deaths in cocaine users (16). In their report, these researchers noted that five individuals were in police custody at the time and that four were placed in hogtie-like restraint positions. These authors suggested that the amounts of cocaine found in these victims did not support a simple diagnosis of cocaine overdose. They felt that the exact cause of death was unknown and speculated that the deaths might be the result of “autonomic reflexes, a toxic cardiac dysrhythmia, or ‘restraint stress’.”

Since this report, others have proposed that this position impairs normal ventilatory function and places such individuals at risk for death by asphyxiation. Based on this postulate, the term *positional asphyxia* has been used to describe these deaths, which appears to represent an entirely different syndrome than what was initially associated with the term in the past, as noted earlier. In 1992, Reay reported three deaths that occurred in individuals who were restrained and placed in the back of police cars (6). All of the victims were violent, agitated, and uncooperative as a result of the use of various intoxicants or psychiatric illness. Assistance by multiple police officers was required in order to subdue these individuals and each one became unresponsive during transport. At autopsy, no clearly defined anatomic cause of death could be determined and it was concluded that these deaths were the result of the combined ventilatory effects of the semi-prone position and the confined space of the patrol cars.

Also in 1992, the San Diego Police Department, in conjunction with the County Medical Examiner's Office, formed a Custody Death Task Force to examine the issues surrounding in-custody deaths. This effort was spurred by seven in-custody deaths, three of which occurred in individuals placed in the hogtie restraint position. The task force conducted a survey of law enforcement agencies nationwide. Approximately 40% of these agencies reported experiencing in-custody deaths. The task force was able to confirm 94 cases of restraint-associated in-custody deaths during the previous decade, however, data collection was incomplete. Approximately 30% of the reporting agencies allowed the use of the hogtie position by officers to control violent individuals. The actual number of hogtie-associated deaths was not determined (3).

In 1993, O'Halloran and Lewman reported 11 cases of sudden death occurring in subjects placed in the prone position. Nine of these individuals were in the hogtie restraint position. All of the subjects were combative, violent, and in an "excited delirious state" as a result of acute psychosis or drug ingestions (most commonly cocaine). Violent confrontation and struggle occurred in all cases. Two of these individuals were subjected to stun-gun shocks shortly before death. The authors asserted that the position "clearly impairs breathing in situations of high oxygen demand by inhibiting chest wall and diaphragmatic movement" (4). In 1995, Stratton et al. were the first to report two individuals who died in the care of prehospital personnel and who had been placed in the prone restraint position for transport because of violent, agitated, and combative behaviors. Both were under the influence of drugs. The authors stated that the prone restraint position leads to "restriction of motion of the diaphragm and chest," and that such positioning "can lead to asphyxia" (5). In 1996, Ross

reviewed 22 cases of sudden death in the prone or hogtie position reported in the medical literature from 1988 to 1993. Of these deaths, 18 occurred in individuals in the hogtie restraint position, 2 were restrained prone on gurneys, and 2 were manually restrained in a prone position. All exhibited violent, combative behavior and fought or struggled with police. Drug use or alcohol intoxication was noted in 16 cases. Cocaine was noted in 12 subjects. Positional asphyxia was listed as the sole cause of death in 5 cases and as a contributing cause of death along with drug intoxication in another 6 cases. Ross concluded that placing a subject in a “confining position which restricts the natural respiratory process” can be fatal and that “based on the risk of sudden death the practice of hogtying and transporting subjects in a prone position should be discontinued” ([17](#)).

### ***EXPERIMENTAL STUDIES***

As should be apparent in all of the cases described here, the diagnosis of positional asphyxia is one of exclusion, as there were no experimental validation of these diagnoses other than prior literature stating that positional asphyxia occurred in these circumstances. The report that all of the above authors (except the first by Wetli) used as a reference to substantiate that the deaths were secondary to respiratory embarrassment was a study by Reay et al. published in 1986 examining the effects of the hogtie position. As this study was the single experimental reference used to supply a physiological rationale for the diagnosis of positional asphyxia in these cases, it is reasonable and probably critically important to carefully examine the methodology, the statistics, and the conclusions of that study in order to better understand the basis for the diagnosis of “positional asphyxia” secondary to the hogtie, hobble, or maximum restraint position.

Reay and his colleagues studied 10 healthy individuals who were placed in the hogtie restraint position or a sitting control position after a period of exercise on a stationary cross-country ski machine that raised the heart rate of the subjects to approximately 120 beats per minute. The authors noted a decline in peripheral oxygen saturation to 85–90% measured by pulse oximeter in these subjects during exercise. The authors then reported statistically significant physiological differences between the group in the hogtie position and the group in the sitting position after the period of exercise. Overall, the subjects in the restraint position had prolonged recovery times after exercise for both heart rate (approximately 35 seconds longer for the restraint group) and peripheral oxygen saturation (approximately 20 seconds longer for the restraint group). On the basis of these findings, Reay postulated, and all of the

authors previously mentioned here accepted, the construct that deaths in individuals placed in the hogtie restraint position were the result of adverse respiratory effects from the body position. Reay further argued that the prone restraint position restricts chest and abdominal movement and therefore reduces ventilatory excursions, placing individuals at risk for hypoventilation hypoxemia and asphyxiation (18).

Before accepting these results, there are some significant methodological and conceptual issues that must be considered. Most importantly, this study is based on the presumption that exercise reduces peripheral oxygen saturation to 85–90% in healthy subjects. Unfortunately, this presumption is at odds with our current understanding of the effects of exercise on gas exchange. In contrast to Reay's observations, previous well-established work in exercise physiology demonstrates that arterial oxygenation improves rather than decreases with moderate exercise in healthy individuals (19,20). This occurs because pulmonary blood flow increases with exercise (i.e., cardiac output increases), and ventilation perfusion ratios throughout the differing lung zones improve, reducing the (A-a)O<sub>2</sub> gradient and also lowering PaCO<sub>2</sub> with still higher levels of exercise (19).

Reay's work is apparently predicated on his observation that oxygen saturation declines with exercise and this in turn was owing to the inappropriate selection of a transcutaneous pulse oximeter to measure oxygen saturation in his exercising subjects (21–23). Arterial blood gas analysis remains the preferred and more accurate method of measuring PaO<sub>2</sub>. Indeed, it is well documented that potentially inaccurate results may be obtained from pulse oximetry when used on exercising subjects (21–23). Second, there appears to be another conceptual flaw in Reay's work. Looking at the data reported by Reay, his conclusion that the differences were statistically significant can only be duplicated if one uses a one-tailed *t*-test to analyze his results. Unfortunately, his work requires the use of a two-tailed *t*-test and if his analysis is repeated using the appropriate statistical methodology the results are no longer statistically significant. Third, even if hypoxemia actually occurred in his subjects following exercise, the hogtie position did not worsen that hypoxemia; it merely prolonged the recovery by 20 seconds (not statistically significant), which does not really support the concept that the hogtie position "causes" asphyxiation. Finally, although heart rate and pulse oximetry measurements were taken in these subjects, no direct measurements of ventilatory function were performed. Given the authors postulate that the hogtie position causes inadequate chest wall and diaphragmatic movements to the point of respiratory failure, it would seem crucial to measure parameters of ventilation. As this article is the sole scientific basis for all of the above-mentioned conclusions concerning the hogtie position,

the claims that this position is inherently dangerous must be viewed with considerable skepticism.

Other more recent work more directly assesses the physiological impact of the hogtie position and gives considerably different results than the work of Reay (24). A study by Chan and his colleagues in 1996 was the first attempt to critically evaluate the physiological consequences of the hogtie position. In this study, volunteers had baseline pulmonary function studies performed in the sitting prone and supine positions. Following this phase, the volunteers were then exercised to a mean heart rate of almost 170 on a bicycle ergometer and then placed either in a standard sitting position or in a hogtie position. Pulmonary function tests were repeated over a 15-minute period and blood gas determinations were made in triplicate from a sample of blood taken from the radial artery via a catheter that was inserted prior to the initiation of the study. The results of the spirometric studies revealed trivial changes in FVC, FEV<sub>1</sub>, and FEV<sub>1</sub>/FVC ratios. These changes were approximately 7% in the prone and supine position and 13% in the hogtie position. The impact of the 13% decline in FVC is graphically displayed in Fig. 3. MVV decreased slightly more with declines of 10, 15, and 23% of predicted values.

Of more importance, however, was that arterial blood gas analyses revealed no change in arterial partial pressure of oxygen (PaO<sub>2</sub>) and in arterial partial pressure of carbon dioxide (PaCO<sub>2</sub>) between the two groups. The latter is particularly important, as it demonstrates no functional effect at all on ventilation from the combination of the hogtie position plus heavy exercise. It is also important to note that these findings persisted for the entire 15-minute period, during which subjects were in the hogtie position following heavy exercise. As would be expected, (A-a)O<sub>2</sub> gradient decreased with exercise and the PaO<sub>2</sub> increased when individuals' oxygen consumption exceeded the anaerobic threshold. These findings are consistent with and expected based on prior work in exercise physiology (19,20).

Schmidt also completed a similar study to that of Reay's and again found markedly different results (25). In this study, 18 volunteers were monitored with baseline measurements and then were exercised on a stationary bicycle to a mean heart rate of 120 beats per minute. Heart rate and oxygen saturation were the parameters studied and no differences were noted in the mean heart rate or in oxygen saturation between the group in the sitting position and the group in the hogtie position. Following this, the subjects were further monitored after more vigorous exercise, which was intended to simulate pursuit and physical struggle. Again, no differences of heart rate or oxygen saturation were noted between the two groups.

Chan and his co-workers have also conducted a second study of the “hobble restraint position” (26). This position is in many respects the same as the “hogtie” position, but the knees of the subject are not as severely flexed as in the hogtie position. The hands continue to be restrained behind the individuals back and the legs are tethered to the wrists, with the knees only flexed to about 90° rather than a tauter position. In this second study, the effects of the hobble position combined with the inhalation of “pepper spray” were compared to the sitting position with and without pepper spray. Once again, no important physiological effects of either the spray, the position or the combination of the two were noted. The same minor changes in ventilatory parameters noted in their first study were again confirmed.

More recently, Parkes (27) attempted to duplicate Reay’s 1988 study. Sixteen subjects were exercised on a bicycle ergometer to a mean heart rate of 120. At that point they were placed in either a seated, supine, or restraint position. No changes in oxygen saturation between the groups was noted, confirming the findings of Chan. Analysis of their data also reveals no significant difference in the heart rate recovery times between the seated and restraint position although they note a difference between the supine position and the restraint position. Unfortunately, an ANOVA was not performed to confirm the significance of these differences.

### *POSITIONAL ASPHYXIA VERSUS RESTRAINT ASPHYXIA*

Despite these carefully performed studies, authors have still ascribed the cause of death of individuals who have been maximally restrained to asphyxia. As it has now been shown that the hogtie position is physiologically of no consequence, it has now been opined (28) that the root cause of “asphyxia” in these cases is downward pressure on the back interfering with ventilatory mechanics rather than the previously indicted hogtie position. That is, asphyxiation occurs not as a result of position (“positional asphyxia”), but as a result of the actual restraint process (“restraint asphyxia”).

In addition, it is further speculated that the weight of the individual (particularly if obese) while in a prone or restrained position is supposed to cause upward pressure on the diaphragm, interfering with its downward excursion, which in turn causes functionally important hypoventilation potentially causing “asphyxia.” As with the previous hypothesis concerning the hogtie position, this construct needs to be examined very carefully in light of other clinical experiences and keeping in mind the paucity of experimental evidence that exists in this arena.

***ASPHYXIATION AND VENTILATORY REQUIREMENTS***

In order to examine the likelihood that an individual might succumb to asphyxiation from weight applied to the back during the struggle to restrain the subject, one must understand the process of asphyxiation. By and large, asphyxiation is the death of the organism secondary to the failure to deliver oxygen to critical tissues and the subsequent failure of critical organ systems. When oxygen delivery fails, either because of inadequate ventilation or inadequate gas exchange, the process is called asphyxiation. Because there are sizable oxygen stores in the body in the form of air in the lungs as well as oxygen in the blood, asphyxiation is a process that takes a considerable period of time in most circumstances. Thus, death does not occur immediately when breathing stops and the process of asphyxiation takes several minutes to occur even when breathing is completely arrested. Should small amounts of breathing continue the process takes even longer.

The critical question then becomes just how much ventilation is necessary in order for someone to survive. In the setting of thoracic surgery, when considering the likelihood that someone will survive a pulmonary resection for lung cancer, most surgeons feel a postoperative vital capacity of 25% of normal is required in order that the individual does not live a “bed-to-chair” existence. Similarly in the emergency department, patients are generally not felt to be at major risk from an asthma attack until flow rates fall to below about 20% of normal. Individuals with Guillain-Barré syndrome or botulism, in which respiratory muscle weakness can occur, are generally felt to be safe enough to breathe on their own until their ventilation falls below 15 mL/kg (65 mL/kg is normal) (29). Thus, 20–25% of ventilatory function appears adequate to maintain life as well as survive major chest surgery and it therefore follows that if position or weight on the back can cause asphyxiation, the weight applied must be great enough to reduce ventilation below these levels. Furthermore, because it takes several minutes to asphyxiate in the setting of no ventilation, when ventilation is reduced to a lesser extent (between 0 and 25% of normal levels), it will take increasingly longer to asphyxiate.

***THE APPLICATION OF WEIGHT/FORCE***

Currently, there are few data available to rely on concerning the effect of added weight on the back. One study has recently been published that directly addresses the issue of weight on the back and the ventilatory effects of that force. In that study, FVC and FEV<sub>1</sub> were compared in the sitting position and in the prone maximal restraint position with 25 pounds and then 50 pounds of

weight between the shoulder blades (30). In addition, oxygen saturation and end tidal carbon dioxide ( $ETCO_2$ ) were measured. No significant differences in either  $ETCO_2$  or oxygen saturation were noted between either the maximal restraint prone position and sitting, or the maximal restraint prone position with weight on the back (either 25 pounds or 50 pounds). Compared to the maximal restraint prone position, the addition of 25 pounds of weight to the back reduced the FVC by 3% and the addition of 50 pounds of weight further reduced the FVC by another 4%. In a similar fashion, the  $FEV_1$  was also reduced. Compared to the maximal restraint prone position, 25 pounds of weight between the shoulder blades reduced the  $FEV_1$  by 5% and the addition of 50 pounds reduced the  $FEV_1$  by an additional 4%. In *vacuo*, such changes are barely outside the range of normal for these parameters, and therefore they would not be expected to produce any clinically relevant effects.

Studies currently underway in our laboratory would indicate that 225 pounds uniformly distributed over the back only reduces MVV to about 60% of predicted (31). Such relatively small incremental changes with increasing amounts of weight on the back should be expected. Maximal inspiratory pressure is one of the best parameters to measure in order to assess the ability of an individual to move gas (ventilate). The greatest inspiratory pressures are normally generated at lower lung volumes. As an extreme example, the maximal inspiratory pressure an individual can generate at total lung capacity (TLC) is zero and thus as lung volumes are reduced by an external load, it would be expected that the maximal inspiratory pressure that could be generated would increase, tending to preserve spirometric indices as external loads increase.

Furthermore the arguments that weight or force applied to the back limits ventilation to the degree that asphyxiation takes place tend to also rely on the notion that the ventilatory effects of additional body weight are worse in the prone position than in the supine position. Yet our experience in clinical medicine would suggest just the opposite. It is now common practice that when gas exchange is severely impaired because of lung disease, critically ill patients are ventilated in the prone rather than in the supine position (32–36). This evidence from the intensive care unit suggests that the prone position improves gas exchange compared with the supine position. There is now a robust body of clinical research that indicates gas exchange is improved in the prone position and furthermore, it also appears that abdominal distention with upward pressure on the diaphragm improves gas exchange (37). Ward and Macklem have demonstrated that although significant chest wall restriction may impede ventilation, restriction of abdominal motion should not influence ventilatory bellows function because diaphragmatic muscle contraction will occur at a more efficient length in much the same way as higher inspiratory pressures can be

generated at low lung volumes (38). Thus, without being able to quantitate the exact effect of weight or force on the back it appears premature to invoke this as a theory to account for these deaths especially in light of the improved gas exchange that appears to occur in this position.

### ***METABOLIC ACIDOSIS***

Still other authors have attempted to invoke “asphyxia” by suggesting that the exertion associated with struggle leads to metabolic acidosis and that restrained individuals are not capable of compensating and normalizing their pH status (by blowing off carbon dioxide) because of the ventilatory impairment occasioned by the restraint position (39). Once again, the data do not support such contentions. Most importantly, even if there were data to support the notion that the hogtie position interfered with ventilation to a degree to cause metabolic acidosis owing to reduced clearance of carbon dioxide in the setting of heavy exercise, the presence of metabolic acidosis does not itself produce asphyxia. As mentioned previously, asphyxia is a process secondary to oxygen deprivation rather than carbon dioxide accumulation or metabolic acidosis. Although it certainly makes individuals uncomfortable, in and of itself the pH generated by even the most intense anaerobic exercise is not dangerous. Perhaps the best example of this in clinical medicine is the physiological effect of a generalized tonic-clonic (grand mal) seizure where significant acidosis can be generated (40).

Moreover, as mentioned earlier, experimental data do not support the contention that the ventilatory response to exercise is in any way blunted by the hogtie position. In a study already cited, individuals were exercised to a mean heart rate of almost 170 beats per minute (24). Following this extremely heavy exercise, they were placed in either a hogtie or sitting position. At the end of 15 minutes in the hogtie position, not only was the  $\text{PaO}_2$  of individuals in the two groups the same, the  $\text{PaCO}_2$  was also the same. As  $\text{PaCO}_2$  is inversely related to alveolar ventilation, the exact same  $\text{PaCO}_2$  in the two groups indicates that the ventilatory response to exercise in these two groups was exactly the same. Thus, there is no evidence that individuals in the hogtie position ventilate any less than their seated counterparts to any degree. The ventilatory response to the combination of the hogtie position and exercise (and the acidosis associated with exercise) is exactly the same as individuals who exercise and are placed in a seated position.

### ***OTHER POSITIONS***

Despite the overwhelming evidence that the hogtie position is in and of itself not a risk factor for “asphyxia,” authors continue to recommend that individuals not be transported in the prone restrained position. Furthermore, they

recommend that when an individual requires restraint for transport, he or she should be turned to the side to reduce the risk of “asphyxiation” (27,39–41). Unfortunately, this recommendation is made without regard to the data that do exist. The left and right lateral decubitus position has not been studied recently regarding its effect on ventilation, however, the one study on the subject that does appear in the literature would indicate that vital capacity is affected no more or less in the right or left lateral decubitus position than in the supine position (42). Coupled with the prior work of Vilke, this would indicate that these decubitus positions have basically the same effect on ventilation as does the prone or supine position and that they offer no advantage to these positions (43). In fact, the prone position is to be preferred compared to the supine position for individuals at risk for aspiration. Classically, the supine position is considered the position of greatest risk for an individual whose level of consciousness is depressed and who is at risk of aspiration. Moreover, case reports have documented similar in-custody deaths in individuals who have been placed in the sitting, supine, and lateral restraint positions; thus refuting the supposed greater “safety” from positional or restraint asphyxia in these positions (39,44).

### *OTHER FACTORS*

Not all authors have accepted the position that restraining an individual in a hogtie or hobble restraint position causes “positional or restraint asphyxia.” As noted earlier, Wetli and Fishbain suggested a variety of contributing factors; none of which were asphyxial in nature (16). Laposata stated that the evidence to cite positional asphyxia alone as the cause of death is insufficient and the position “is not itself a position that would be expected to be fatal within minutes” as has been reported in many cases (45). A series of cases from Philadelphia raises the question of whether minor head injury may somehow be related to these deaths, but also points out the well-documented changes in cardiovascular physiology associated with cocaine abuse (46). The authors then go on to state “sudden death during restraint of individuals under the influence of cocaine is most likely the result of these sympathomimetic effects of cocaine.” Glatter and Karch applied the “fundamental tenets of basic exercise physiology” to conclude that “the mere act of restraining an agitated individual cannot possibly lead to significant hypoxia (and thus death) unless, of course, there is some preexisting problem with central cardiac output, peripheral oxygen extraction, or oxygen utilization.” Using assumptions available in “any basic physiology textbook,” they concluded that as “the body has such massive oxygen reserves, and since it has been amply demonstrated that “hog-tying” has only negligible effects on ventilation, we therefore conclude that the diagnosis

of “positional asphyxia,” by itself, is not a sufficient cause of death, and that other causes for death should be considered” (47).

Recently, a series of sudden deaths in individuals requiring restraint were reported by Stratton (48). This is a retrospective but consecutive study from 1992 to 1998 and represents a series of individuals for whom emergency medical services (EMS) were called and for whom restraint (because of excited delirium) was required. Eighteen deaths occurred in this group and an entrance criterion for the study was that the EMS personnel witnessed the arrest. Factors that were associated with these deaths were then described. As mentioned previously, an entrance criterion for this study was restraint, and therefore, not surprisingly, the authors report that all of the victims were restrained. All were in the prone hobble position, all had a forceful struggle against restraint, and 80% tested positive for stimulants (cocaine, amphetamines, or both). The 18 individuals who died were restrained, with the wrists and ankles bound and attached behind the back. All 196 of the individuals who survived were similarly restrained. Also of note is that for the last 2 years of the study, the position that was recommended for the individuals who were restrained changed. Prior to 1996, patients were restrained in a prone hogtie position. Subsequent to 1996, the less restrictive hobble (also called the total appendage restraint position [TARP]) was used. The death rate while individuals were restrained in the hogtie position was 11%. The death rate remained at 11% after the TARP was adopted.

This is an important study for a variety of reasons. As EMS personnel were on hand and witnessed the arrest, the time between the arrest and the initiation of resuscitative measures must be presumed to be short (although it was not reported). Furthermore, autopsy data concerning the height and heart weight of the individuals were reported for the victims. Analysis of their data reveals that of the 18 individuals, 9 had heart weights that were above 2 standard deviations (SD) from the norm when the height of the individual was used to assess normal heart weight and 2 had heart weights more than 1.5 SD from the norm (49). As only 2.5 % of a normal population will have a heart weight above 2 SD from the norm, the fact that half of this study group was greater than 2 SD, strongly suggests that underlying cardiovascular disease was over-represented in this population. This is not surprising in light of the fact that 45% of this population was reported to have known chronic cocaine use. It is also of note that apparently no cardiac arrests occurred in which there were successful resuscitations. The combination of the presumed short interval between the occurrence of cardiac arrest and resuscitative measures, coupled with the observation that there were no successful resuscitations, strongly suggests that asphyxiation did not play a role in these deaths and that the pathology was predominantly cardiac. This low rate of resuscitation is in keeping with the nationally reported

outcomes of cardiac arrests due to heart disease in large cities ([50](#)). Finally, the lack of an effect on overall mortality rate by the change in restraint policies in the middle of the study period would also suggest that position had no important effect on the rate of death.

## SUMMARY

Individuals who are out of control and are a risk to either the public or themselves will continue to attract the attention of law enforcement. Because of their behaviors, such individuals are unlikely to readily comply with instructions of either police officers or prehospital personnel. Thus, intervention by the police is almost inevitable. Given the risk of the underlying drugs or exertion that are involved in these situations, it is to be expected that sudden cardiac death may be a consequence of such an interaction. In many respects, such deaths are no more surprising than the death of an individual with occult heart disease shoveling snow after a winter storm. Based on the data that currently exist, the hogtie, maximal restraint position (hobble) or the prone position appear to be no more physiologically disruptive than any other position and insofar as they protect the individual from harming him or herself (e.g., from aspiration) or others, they are, from a medical point of view, perfectly acceptable positions in which to restrain and transport violent and out-of-control individuals. The hypothesis that the maximal restraint position (either hobble or hogtie) in some way places the restrained individual at risk for positional or restraint asphyxiation is not supported by the overwhelming majority of the experimental data that currently exist.

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